Environmental Aspects of Dredging: What About Air Quality?

Mark J. Anderson[1] and Brian D. Barkdoll[2], F.ASCE

[1]USACE, Rock Island District, IL, 61204, PH (309) 794-5735 ext.6108, FAX: (309) 794-5712, email: mark.j.anderson@usace.army.mil
[2]Civil & Environmental Engineering Dept., Michigan Tech University, Houghton, MI 49931, PH: (906) 487-1981, FAX: (906) 487-2943, email: barkdoll@mtu.edu

ABSTRACT

Dredging has historically been important for keeping the nation's waterways navigable, mining, and more recently for the removal of contaminants and restoring natural habitat. The placement of dredged material, re-suspension of sediments, and contaminated dredged material could all result in adverse environmental impacts. These impacts have all been, and are being, studied extensively. What has not been investigated, however, are the air emissions resulting from dredging operations. The incorporation of air emissions into management decisions such as the selection of dredging technology is needed and would allow decisions based on environmental impacts and not solely on cost. This analysis lends itself to a limited life cycle and ecoefficiency analysis.

IMPORTANCE OF DREDGING

Dredging is the underwater excavation of accumulated sediments. The removal of sediment from a water body can be done for several reasons. The primary purposes are: navigation, mining, ecosystem restoration, and the removal of contaminants. Once sediment has been removed from the channel it is referred to as dredged material. In fiscal year (FY) 2006 the U. S. Army Corps of Engineers (USACE) dredged a total of 204.2 million cubic yards (CY) of sediment (NDC 2007). Navigation maintenance dredging accounted for 137.8 million CY or 67.5% of this total. Two types of dredging equipment performed 66.6% of the total dredging completed in FY 2006. Cutterhead pipeline dredges removed 118.6 million CY of material or 58.1% and mechanical dredges removed 17.4 million CY or 8.5% of the total material dredged in 2006.

Navigation maintenance dredging is an integral and necessary operational component of our waterborne transportation system. Waterborne commerce in the United States totaled 2,588 million short tons in 2006 (IWR 2006). Of that total 702.1 million short tons were transported within the Mississippi River System with 490.6 million short tons being classified as internal traffic. Internal traffic is defined as "vessel movements (origin and destination) which take place solely on inland waterways. An inland waterway is one geographically located within the boundaries of the contiguous 48 states or within the boundaries of the State of Alaska" (IWR 2006). Nearly 25% or 120.4 million short tons of the Mississippi River System internal traffic were transported on the Illinois Waterway. The waterborne transportation system would be crippled if navigation maintenance dredging was not performed in a regular and timely manor.

TYPES OF DREDGES

There are numerous types of dredges used for the various purposes including: cutterhead pipeline (CPD), mechanical bucket or clamshell (MBD), hopper, sidecaster,

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and dustpan dredges. Each type of dredge is well suited for different site conditions (both dredge cut and placement site), sediment characteristics, quantities of sediment to be dredged, production rates, and distance that the material must be transported to a placement site (USACE 1983).

COMPARISON OF DREDGING METHODS

The type of equipment included in this analysis will be limited to that which is commonly used for navigation channel maintenance dredging on the Illinois Waterway (IWW) and Upper Mississippi River (UMR) within the U. S. Army Corps of Engineers, Rock Island District. The equipment selected was used by Rock Island District for navigation channel maintenance dredging on the IWW during the 2005 dredging season. It included a 16-inch cutterhead pipeline dredge owned and operated by an independent contractor and a mechanical bucket dredge owned and operated by Rock Island District (Graham 2007/08).

Cutterhead pipeline dredges are capable of pumping dredged material approximately 5,000 to 12,000 feet with just the pump on the dredge itself, depending on the size dredge, elevation change to the placement site, and sediment characteristics. In order to transport dredged material over longer distances, additional inline booster pumps must be added. Typically, only two booster pumps can be efficiently added to the dredging process, increasing the transport distance by 1,000 to 3,000 feet per booster pump. If the distance between the dredge cut and placement site exceeds the total distance with booster pumps then an intermediate placement site within the water body must be identified and approved. The sediment would be dredged to this intermediate placement site then the dredge would be moved from the original dredge cut to the intermediate placement site and the material would be dredged a second time and transported to the final placement site, commonly referred to as re-handling or double handling the dredged material. This process significantly increases the environmental impacts and the cost per CY which usually makes a cutterhead pipeline dredge unsuitable for dredging and transporting dredged material distances greater than that reachable with two booster pumps. The transport distances for the 16-inch contractor-owned dredge used by Rock Island District for the 2005 dredging season are 8,000 feet for the dredge alone, with each booster pump capable of increasing the transport distance by 2,000 feet. Once a cutterhead pipeline dredge has been mobilized and set up at a dredge cut it is capable of nearly continuous dredging with few interruptions except for routine maintenance for the equipment, movement of the discharge pipeline to minimize delays to navigation, and relocation of the pipeline within one or to another placement site. This results in relatively high production rates. Cutterhead pipeline dredges generate a considerable quantity of water that must be managed at the placement site to meet water quality standards.

Mechanical bucket dredges are well suited when the dredge material must be transported distances greater than 12,000 feet. Once the material has been dredged and loaded onto a barge it can be transported long distances without requiring re-handling. Another situation where mechanical bucket dredges are well suited is for small quantities of material to be dredged from one location, because they are relatively quick and inexpensive, compared to cutterhead pipeline dredges, to mobilize and demobilize. Another consideration for dredging equipment is the distance from the river channel to

the placement site. Either an excavator or a dozer would be used to transfer the dredged material from the barge to the placement site as long as the site is adjacent to the river channel. If the placement site is not immediately adjacent to the channel, material dredged by a mechanical bucket dredge would need to be transferred from the barge to a truck for transport overland to the placement site. This would add expense, negative environmental impacts, and reduce production rates over a cutterhead pipeline dredge. A cutterhead pipeline dredge could extend the discharge pipeline over land to the placement site as long as the total transport distance doesn't exceed the maximum distance for that dredge.

Each type of dredge has distinct advantages and disadvantages that contribute to the decision-making process (USACE 1983). Mechanical bucket dredges are quicker and more economical to mobilize, are capable of transporting dredged material over long distances, require less supporting equipment, and have relatively low production rates. Cutterhead pipeline dredges are more difficult and costly to mobilize, are limited in the distance they can transport dredged material, require more support equipment, and have relatively high production rates. In general terms this means that mechanical bucket dredges are better suited to small quantities of material to be dredged at a given location and/or long (greater than 12,000 feet) transport distances while cutterhead pipeline dredges are better suited to large quantities and shorter transport distances (less than 12,000 feet).

Typically, dredging decision makers utilize multiple criteria for selection of dredging equipment and placement site for each dredge cut(s) (USACE 2003-A). These criteria are used to identify and implement the most suitable combination of equipment and placement site(s) for navigation channel maintenance dredging over a 20 to 40 year planning horizon.

DREDGED MATERIAL PLACEMENT SITES

Dredged material placement sites used in Rock Island District fall into five broad categories including: thalweg, bankline, near shore, upland, and confined. The thalweg is the deepest part of a river channel cross section which usually has the highest flow rates. A bankline placement site would be within the flood plane and immediately adjacent to the river channel. Beach nourishment would be one example of a bankline placement site. Near shore placement sites would also be located within the flood plane but further away from the river channel than a bankline placement site. Upland placement sites are located outside of the flood plane, frequently behind a levee. Confined disposal placement sites are engineered facilities that contain dredged material within a specified footprint.

Thalweg Dredged Material Placement Sites

Thalweg placement of dredged material could be done using either a cutterhead pipeline or mechanical bucket dredge. The site would be located in a reach of river that is particularly deep, usually 20 to 30 feet in depth or more, this compares to the navigation channel mandated minimum depth of nine feet. Not all reaches of the UMR or IWW have thalweg conditions that are suitable for dredged material placement. This is not a particularly desirable option since it does not remove the sediment from the river channel and could result in additional environmental impacts. There are some

advantages to thalweg placement that must be taken into account before eliminating this type of placement site from consideration. Thalweg placement is economical as long as the distance between the dredge cut and placement site are within the dredges transport distance capabilities. Also, there is no return water to manage when using a cutterhead pipeline dredge.

Bankline Dredged Material Placement Sites

Bankline placement could be done using either a cutterhead pipeline or mechanical bucket dredge. The dredged material is placed on the river shore or bankline for habitat restoration, beach replenishment or nourishment, or erosion protection. A bankline placement site for habitat restoration could be to stabilize tree root systems that have been exposed due to erosion, increase the land surface elevation in areas to provide safe havens for wildlife to use during flood events, and create or enhance islands. Recreational facilities along the river are highly desirable to state and local governments along with the public. Dredged material can be used to nourish beaches and enhance the recreational experiences for boaters and swimmers. On occasion dredged material can be placed on banklines for erosion protection of cultural and historic sites that are not easily accessible for more traditional erosion protection systems such as riprap. In addition, dredged material can be used as short-term erosion protection or as fill to restore a bankline in preparation for riprap or some other erosion protection system.

Near Shore Dredged Material Placement Sites

Near shore placement sites would include those sites that are within the floodplain but beyond the bankline. These placement sites can be used for habitat restoration similar to bankline sites or as long-term placement sites. The preferential option for long-term placement sites is typically to locate them outside of the floodplain to avoid adverse impacts to flood water surface elevations and the risk of re-suspension of the sediment and transport back into the river channel during high water events. However there are locations where the floodplain extends beyond practical and economical limits of transporting dredged material so near shore sites must be considered.

Upland Dredged Material Placement Sites

Upland sites are located outside the floodplain and are typically the preference of resource and regulatory agencies since they will have no impact on flood water surface elevations and they eliminate the potential for transport back into the river channel during floods. Upland sites could include: placement on the landside of levees (as long as the level of flood protection is not increased); placement on existing agricultural fields; beneficial use stockpiles; and for habitat restoration.

Confined Dredged Material Placement Sites

Confined dredged material placement facilities (CDF) are engineered and constructed sites that will retain the dredged material within a specified footprint. CDFs can be used for island creation, long-term dredged material placement sites, commercial and recreational site development, and for contaminated dredged material to ensure contaminates do not migrate off-site.

DREDGING EQUIPMENT EMISSIONS TO THE ATMOSPHERE

Navigation channel maintenance dredging equipment used on the IWW and UMR, as with most locations, needs to be mobile and capable of operation without an external power source, making diesel fuel the predominate choice. All of the equipment included in this study is diesel powered. The combustion of diesel fuel releases pollutants into the atmosphere that can be quantified and compared between dredging crews to determine the lowest adverse environmental impacts for each type of equipment and scenario. These contaminants impact air quality and may add to global climate change considerations.

CURRENT KNOWLEDGE

The U.S. Army Corps of Engineers (USACE) was first tasked with maintaining and improving a waterborne navigations system in 1824. Deepening and clearing out rivers and harbors was added to the USACE responsibilities in 1826 (USACE 2007) and remains an integral part of the USACE mission. Typical types of equipment and placement sites utilized for navigation channel maintenance dredging are outlined in the ”Types of Dredges” and ”Dredged Material Placement Sites” sections respectively. USACE, both independently and in collaboration with the U. S. Environmental Protection Agency (USEPA), have developed several manuals for dredging operations, including dredged material placement sites, and environmental impacts from dredging.

Even though navigation maintenance dredging has been done for hundreds of years the environmental effects are fairly recent considerations. Environmental impacts of dredging have been studied and documented with most of the information having been developed over the past 10 to 15 years (Bridges 2008). The areas of primary focus have been the identification and implementation of beneficial uses for dredged material, environmental dredging, emissions to air from the placement and/or re-suspension of contaminated dredged material, and the regulation of emissions to the air from marine engines. Though environmental impacts of dredging have been studied, no efforts have been applied to the evaluation of air emissions from comparable types of dredging equipment, as in this study.

Beneficial Use of Dredged Material

Beneficial use of dredged material is it’s productive use as a resource material. Some possible uses include construction materials, aquaculture, topsoil, beach nourishment, berm creation, capping, land creation, land improvement, fill, shore erosion protection, habitat enhancement, and wetland restoration.

The Great Lakes Commission, responding to the findings of the Great Lakes Beneficial Use Task Force, has identified the beneficial use of dredged material as a “priority management option” and has adopted a resolution for increasing federal funding, research, and USACE authority for beneficial use (Pebbles 2002). The emphasis on identifying and implementing beneficial uses for Great Lakes dredged material will help to minimize environmental impacts from dredging but does not address the air emissions from dredging equipment.

The loss of Louisiana coastal wetlands is being addressed through the beneficial use of dredged material. USACE, New Orleans District has utilized approximately 27 million CY of the 90 million CY of sediment dredged from federal navigation channels

for coastal wetlands restoration projects. This has resulted in the restoration of approximately 10,000 acres of wetlands (Creef and Mathies 2002).

The Illinois River, a major segment of the Illinois Waterway, is part of a large flyway for North American migratory birds. Extensive sedimentation in the backwaters has severely degraded this habitat. The restoration of this migratory flyway will require the removal and placement of a considerable volume of sediment (Marlin and Darmody 2002). Beneficial use applications for this dredged material are being investigated including: island creation and enhancement, topsoil, fill, and urban renewal (Marlin and Darmody 2002).

USACE, Rock Island District has been actively involved in identifying and implementing beneficial uses for navigation channel maintenance dredged material. Examples of beneficial uses for dredged material from the IWW and UMR are levee repair, island creation, fill/construction materials, beach nourishment, and habitat enhancement.

Environmental Dredging

Environmental dredging can be defined as "dredging performed specifically for the removal of contaminated sediments for the purpose of remediating environmental risks" (Bridges 2008). An environmental dredging workshop sponsored by the U.S. Army Corps of Engineers (USACE) and U.S. Environmental Protection Agency (USEPA) focused on re-suspension of sediments, release of contaminants from in-situ and suspended sediments, residual contaminated sediments, and environmental risks (Bridges 2008). None of these focus areas included the air emissions from dredging operations.

According to W. D. Rokosch and N. J. Berg, selection of the best dredging technique for a particular project should be based on several criteria including: dredging location conditions such as water depth, extent of dredge cut, navigation, structural obstructions, sediment characteristics, potential for debris, and underwater structures; environmental regulations; cost considerations; and the positive and negative effects of the dredging operations (Rokosch and Berg 2002). None of the considerations for selection of dredging techniques are air emissions from the dredging equipment.

Several stakeholders from four European countries, France, the United Kingdom, Belgium, and the Netherlands, developed New!Delta, a project to promote the sustainable development of ports and port related activities. One of New!Delta's strategies is sustainable dredging defined as "a strategy in which management of dredging operations is a part of an integrated estuary management that strikes a balance between environmental, economic, social and technical aspects while respecting the legal requirements" (NEW!Delta 2007). The focus of their sustainable dredging strategy is on the potential changes to the physical and sedimentary processes, ecology and habitats, and the existing and future use of the estuary. The primary effects of dredging and dredged material disposal, as outlined in their report, include changes to the hydromorphology, loss of habitat, sedimentation, suspended sediment and turbidity, dispersion of contaminated sediment, reduction in oxygen levels, and disturbances such as noise, light, and movement (New!Delta 2007). Again, there is no consideration for the air emissions from the dredging equipment included in their sustainable dredging strategy.

A rating system similar to that used with Leadership in Energy and Environmental Design (LEED) could be utilized to promote sustainable port development and operation (Abood 2007). The LEED system includes the following six categories: "1.) sustainable sites, 2.) water efficiency, 3.) energy and atmosphere, 4.) materials and resources, 5.) indoor environmental quality, and 6.) innovation and design process". A total of 69 points can be awarded within these categories. According to Abood LEED Categories 4, Materials and Resources, and 6, Innovation, would be the primary sources for dredging and dredged material placement to achieve points (Abood 2007). These points could be received for beneficial use of dredged material, enhancement of aquatic life, and minimizing the loss of habitat. In addition, LEED Categories 2, Water Efficiency, and 5, Indoor Environmental Quality could achieve points for dredged material treatment and reductions in dredging equipment air emissions (Abood 2007). Specifically, Abood identifies the reduction in emissions from ships through the use of alternative fuels, retrofitting engines, addition of emission reduction devices such as catalysts, and reductions in light loading and tidal delays by deepening channels. Interestingly, the deepening of channels would require additional dredging that could increase rather than reduce air emissions. This study addresses reductions in air emissions but does not look at selecting the dredging equipment that would reduce emissions while maintaining navigation channel dredging.

The U.S. Environmental Protection Agency (USEPA) and USACE have collaborated in the development of a document titled "Evaluating the Environmental Effects of Dredged Material Management Alternatives – A Technical Framework" (USEPA, 2004). This framework provides overall guidance for the application of detailed testing manuals developed by USACE and USEPA. These technical testing and design manuals address aquatic and terrestrial impacts from the dredging and placement operations, including the potential for volatization of contaminants into the atmosphere. None, however, consider the air emissions from the dredging equipment in the design and equipment selection process.

Dredged Material Emissions to the Atmosphere

Emissions to the atmosphere from dredging operations include the volatization of chemicals from contaminated dredged material within both the placement site and re-suspended in the water column and emissions from marine engines used to power dredging equipment. The rate at which specific chemicals volatize from dredged material has been studied using various models. Volatization rates for hydrophobic organic compounds from four different locations were modeled to tentatively rank the magnitude of emission rates. The four locations were the dredging location or cut, the exposed placement site location, the ponded placement site location, and the placement site location with vegetated cover (Valsaraj 1995). The results indicated that the greatest emissions resulted from the exposed placement site followed by the dredge cut location with high levels of suspended solids (Valsaraj 1995). Air quality impacts from odorous or toxic compounds in dredged material and effects on inhabitants near dredging operations can be costly to control (Zimmer 2004). Multiple models were tested with differing operational and remediation alternatives. The results were evaluated against acute air quality standards and odor threshold (Zimmer 2004). Neither of these studies considered the air emissions from dredging equipment.

Regulation of Air Emissions From Marine Engines

Air emissions such as Nitrogen Oxides (NOx) from marine engines are being regulated under both the USEPA's "Control of Emissions of Air pollution from New Marine Compression Ignition Engines at or Above 37 kW" and Individual State Implementation Plans (SIP) (Gore 2002). Actions taken to comply with these standards include using shore power instead of marine power when tied up to pier, voluntarily reducing speed when in port to below normal, and potentially limiting industrial equipment operations to a specified number of hours each day (Gore 2002). These standards address air emissions but do not examine the dredging equipment selection process as a source for reducing emissions to the atmosphere.

The significance of United States port air quality concerns are increasing. In response, the USEPA generated the transportation and general conformity rules (Rhoads 2004). These rules require project sponsors to include air quality analysis in their planning process. An approach has been developed based on emission reduction plans that allow projects to maintain general conformity status. Cost estimates are developed that include the type and size of equipment to be used, production rates, hours of operation, and labor requirements that meet existing standards without supplementary air emission control considerations (Rhoads 2004). This approach utilizes a similar approach to that done in this study for quantifying air emissions from diesel equipment but does not use the results for selection of equipment. Nor does it focus on navigation maintenance dredging but considers all equipment required for unspecified projects.

SUMMARY

Considerable effort has been put forth to identify and reduce environmental impacts from dredging operations. Reductions in adverse impacts have been achieved through the identification and implementation of beneficial uses for dredged material, development of environmental dredging techniques, minimization of the volatization of compounds from contaminated dredged material, and striving toward compliance with air quality standards. The reuse of dredged material for construction materials, aquaculture, topsoil, beach nourishment, berm creation, capping, land creation, land improvement, fill, shore erosion protection, habitat enhancement, and wetland restoration has minimized the need for long-term placement sites and the resulting impacts to both aquatic and terrestrial environments. Removal of contaminated sediments minimizes the risk of contaminants migrating into the water column or biota. Identifying solutions that minimize volatization of contaminates from dredged material either from a placement site or when re-suspended in the water column help to reduce environmental impacts. In addition, the adaptation of air quality standards for marine engines reduces adverse impacts to the environment. All of these efforts significantly improve the sustainability of dredging operations and reduce environmental impacts. One potential area for reducing adverse environmental impacts that is conspicuously missing from this list is the quantification and selection of comparable dredging equipment based on the air emissions. By identifying the type of dredging equipment with the lowest air emissions, when cost, site conditions, and equipment availability are comparable, environmental impacts can be minimized without compromising the dredging project.

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